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(54) **ANTENNA WITH BRIDGED GROUND PLANES**

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H01Q 1/48 (2006.01)
H01Q 9/04 (2006.01)
H01Q 23/00 (2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 1/48*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 9/045*** (2013.01); ***H01Q 9/0407*** (2013.01); ***H01Q 23/00*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/48; H01Q 23/00; H01Q 9/0414; H01Q 1/526; H01Q 9/0421; H01Q 9/0407; H01Q 1/38
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,012,571	B1 *	3/2006	Ozkar	H01Q 1/243 343/702
7,928,915	B2	4/2011	Sanz Arronte et al.	
8,330,259	B2	12/2012	Soler Castany et al.	
8,593,360	B2	11/2013	Baliarda et al.	
2004/0201523	A1 *	10/2004	Yuanzhu	H01Q 1/3275 343/700 MS
2007/0120748	A1	5/2007	Jenwatanavet et al.	
2010/0201588	A1	8/2010	Chen	

(Continued)

FOREIGN PATENT DOCUMENTS

EP 2099093 A1 9/2009

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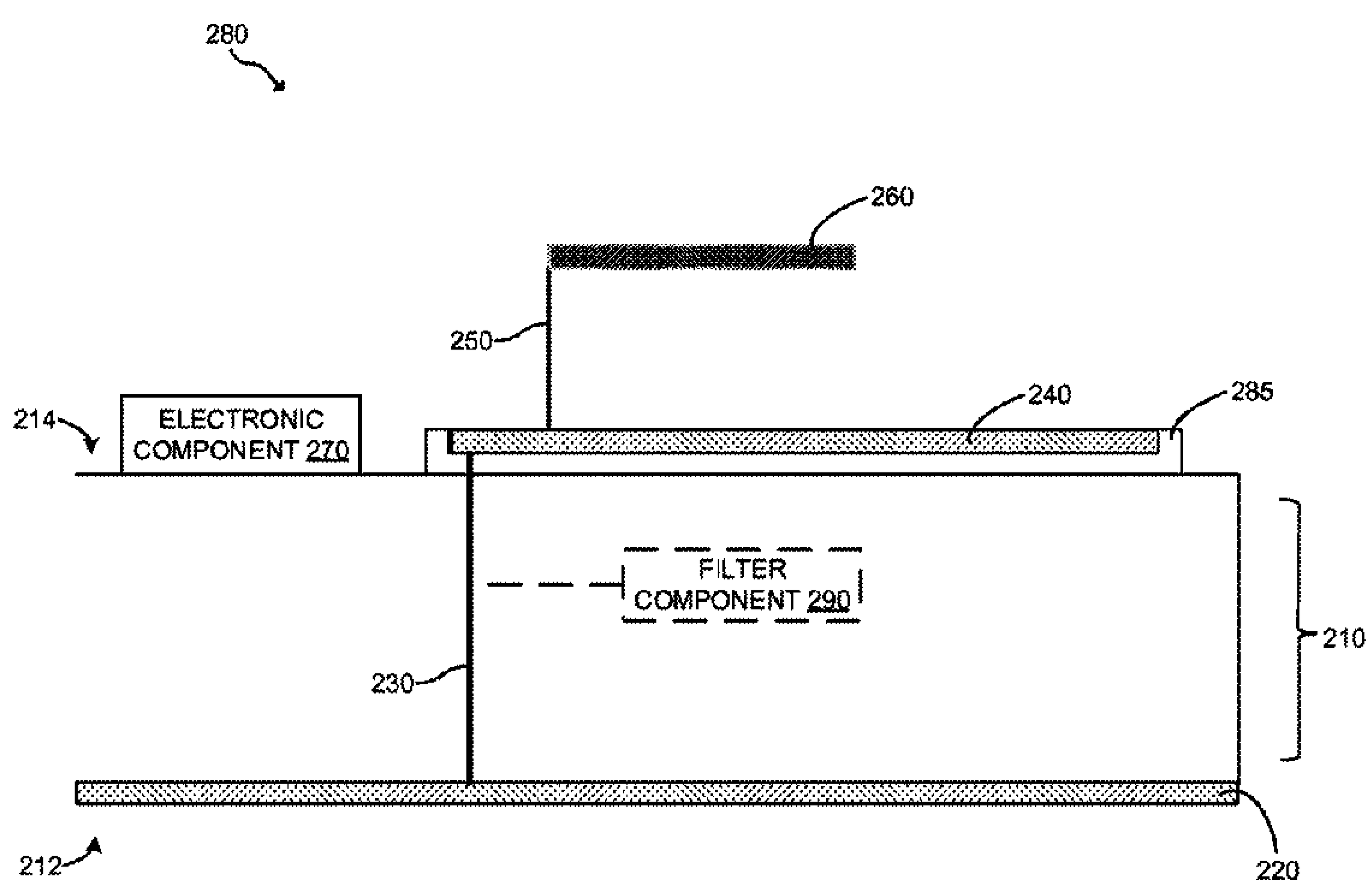
(57) **ABSTRACT**

An antenna system with a bridged ground plane includes a printed circuit board, a first ground plane, a bridge, an antenna radiating element, an antenna connection, and at least one electronic component. The first ground plane is coupled to a first face of the printed circuit board. The bridge couples the first ground plane to the second ground plane. The antenna radiating element is coupled to the second ground plane via the antenna connection. The electronic component or components are coupled to a second face of the printed circuit board.

18 Claims, 5 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0006953	A1	1/2011	Chiang et al.	
2011/0170268	A1 *	7/2011	Takemura	H01L 23/552 361/748
2012/0092226	A1 *	4/2012	Baliarda	H01Q 9/0421 343/848
2012/0249386	A1	10/2012	Yanagi et al.	
2012/0322373	A1 *	12/2012	Washiro	H01Q 1/2266 455/41.1
2013/0169504	A1	7/2013	Jenwatanavet	
2016/0056544	A1 *	2/2016	Garcia	H01Q 21/28 343/725

* cited by examiner

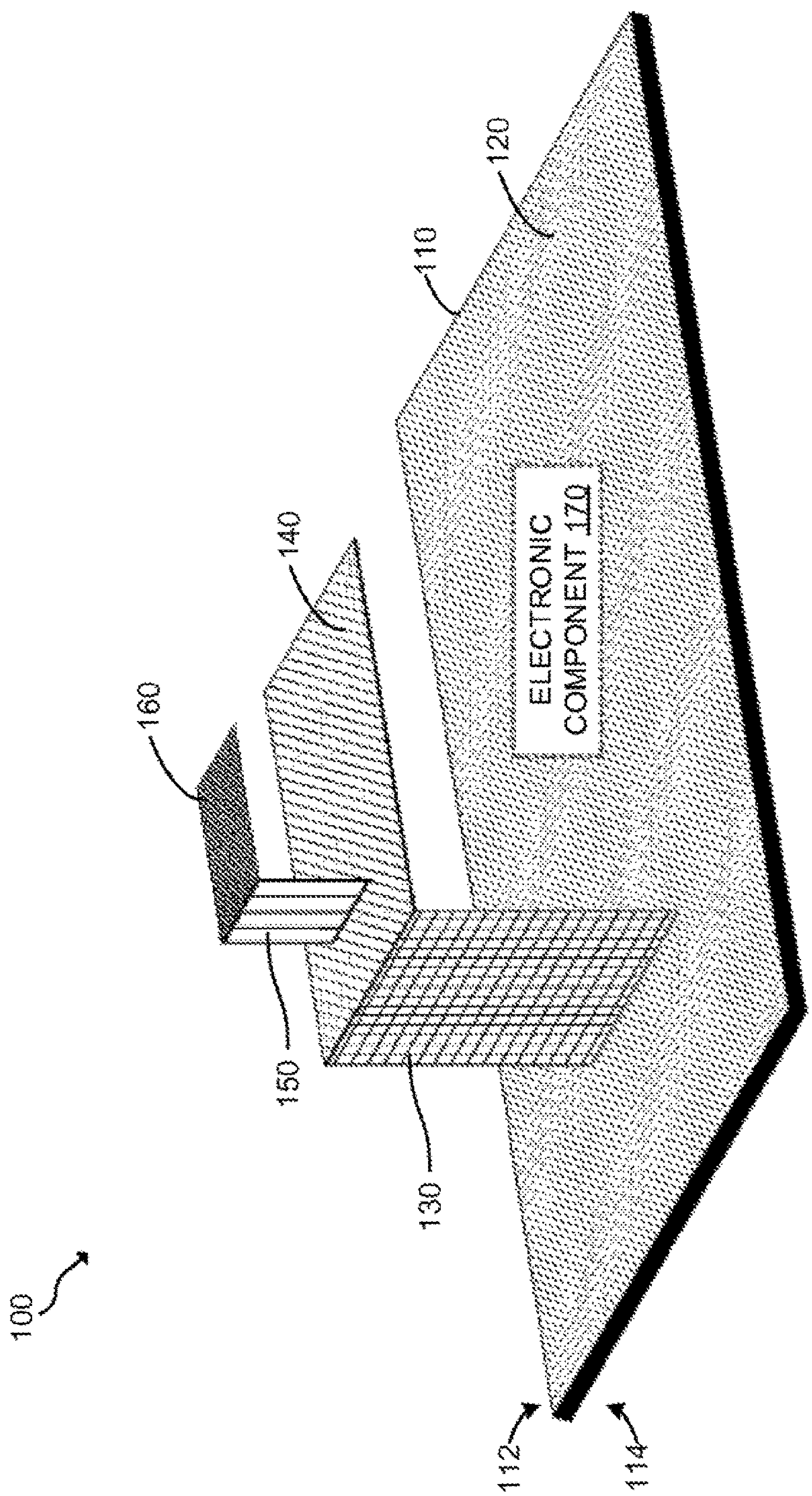


FIG. 1

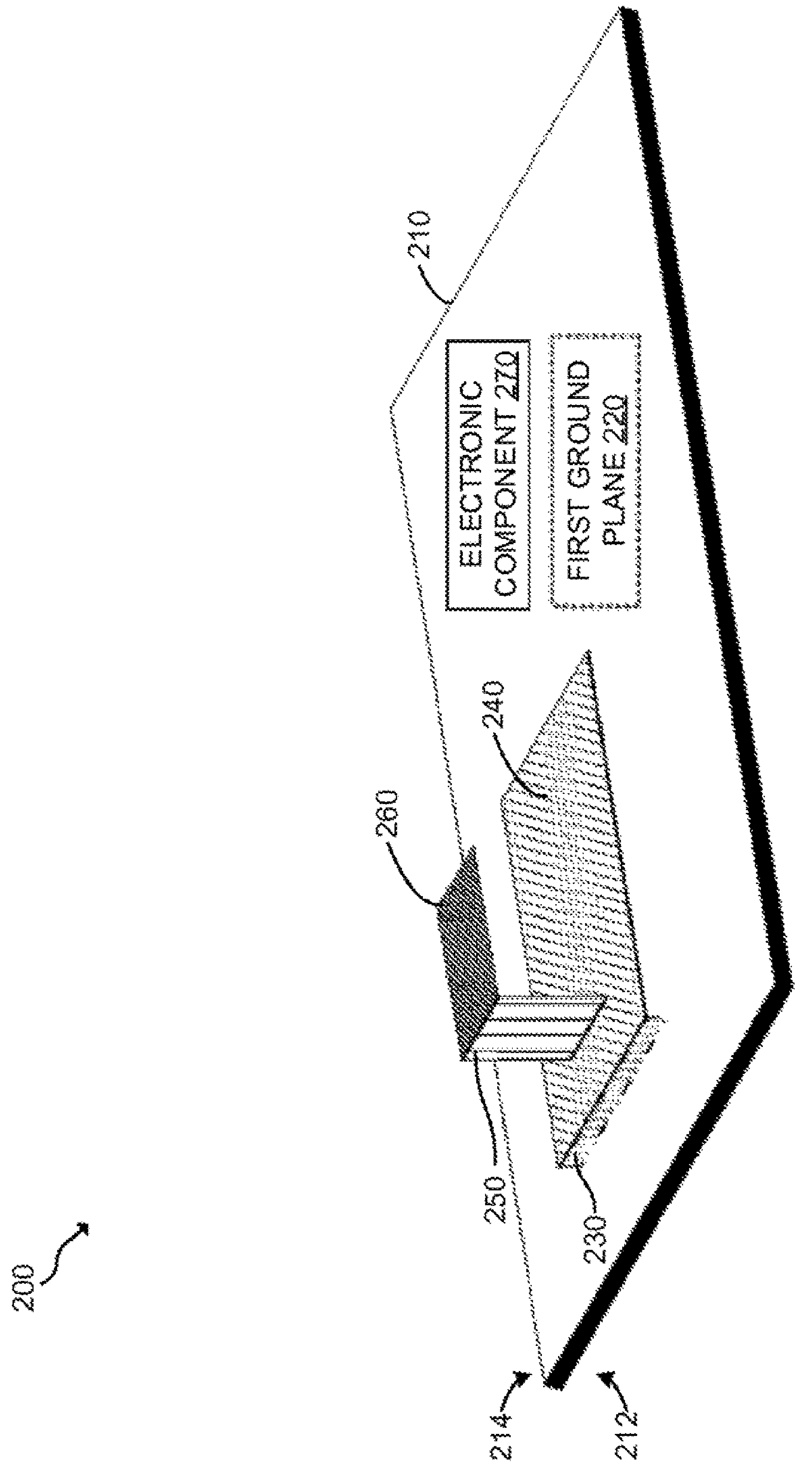

200
210
ELECTRONIC COMPONENT 270
FIRST GROUND PLANE 220
240
260
250
230
214
212

FIG. 2A

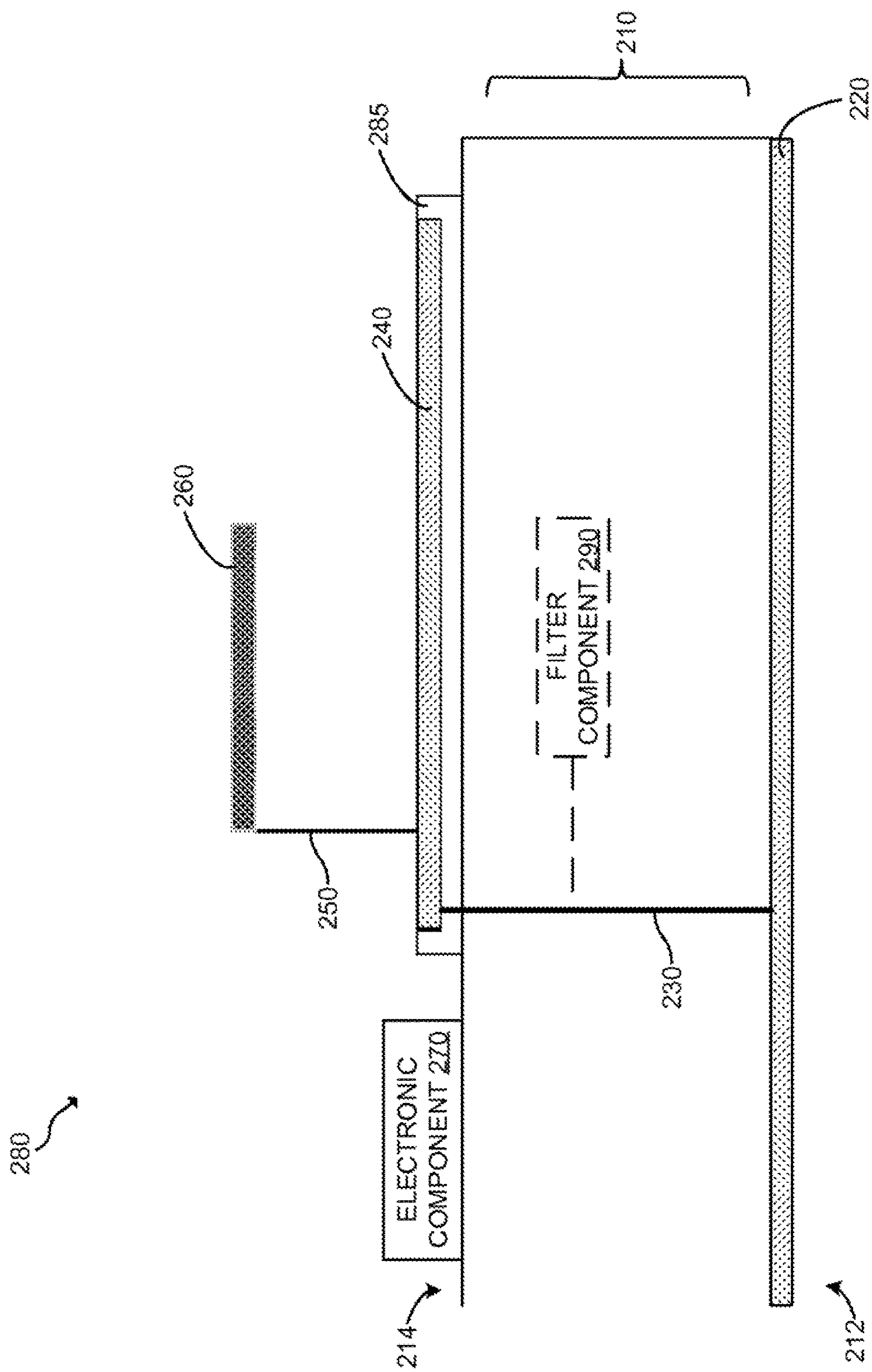

210
220
285
240
260
FILTER
COMPONENT 290
250
230
ELECTRONIC
COMPONENT 270
280
214
212

FIG. 2B

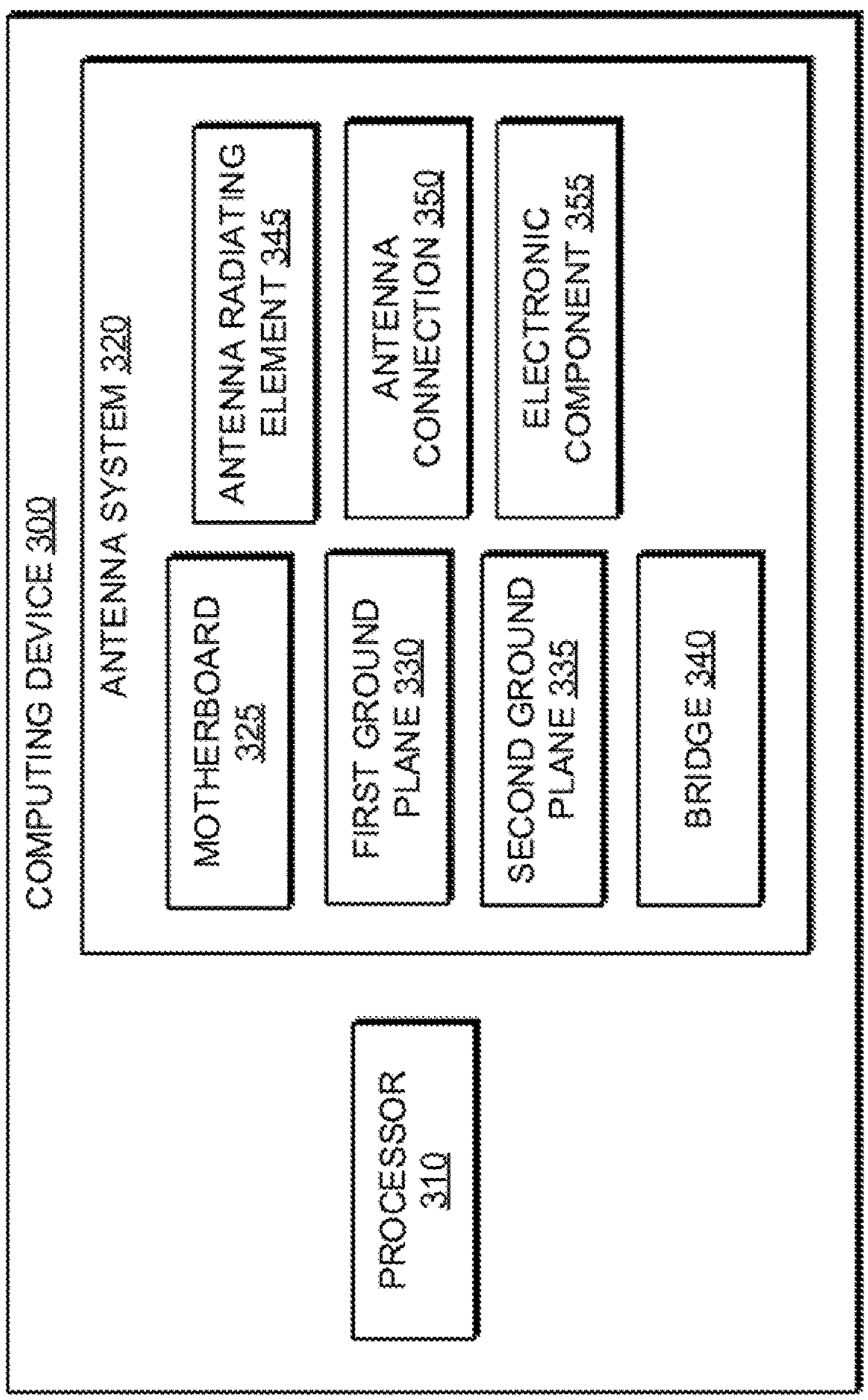

COMPUTING DEVICE 300
ANTENNA SYSTEM 320
MOTHERBOARD 325
FIRST GROUND PLANE 330
SECOND GROUND PLANE 335
BRIDGE 340
ANTENNA RADIATING ELEMENT 345
ANTENNA CONNECTION 350
ELECTRONIC COMPONENT 355
PROCESSOR 310

FIG. 3

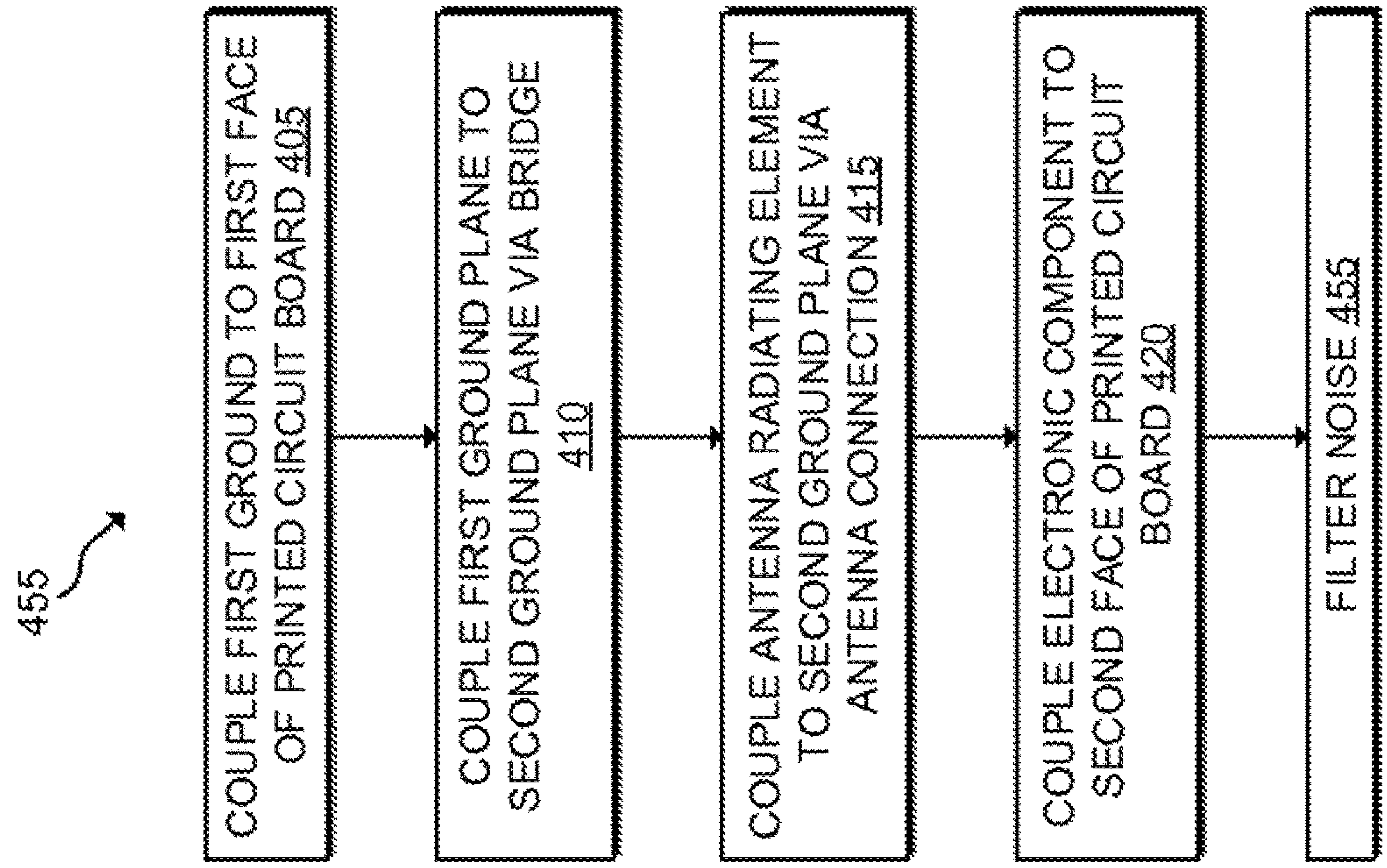

455
COUPLE FIRST GROUND TO FIRST FACE OF PRINTED CIRCUIT BOARD 405
COUPLE FIRST GROUND PLANE TO SECOND GROUND PLANE VIA BRIDGE 410
COUPLE ANTENNA RADIATING ELEMENT TO SECOND GROUND PLANE VIA ANTENNA CONNECTION 415
COUPLE ELECTRONIC COMPONENT TO SECOND FACE OF PRINTED CIRCUIT BOARD 420
FILTER NOISE 455

FIG. 4B

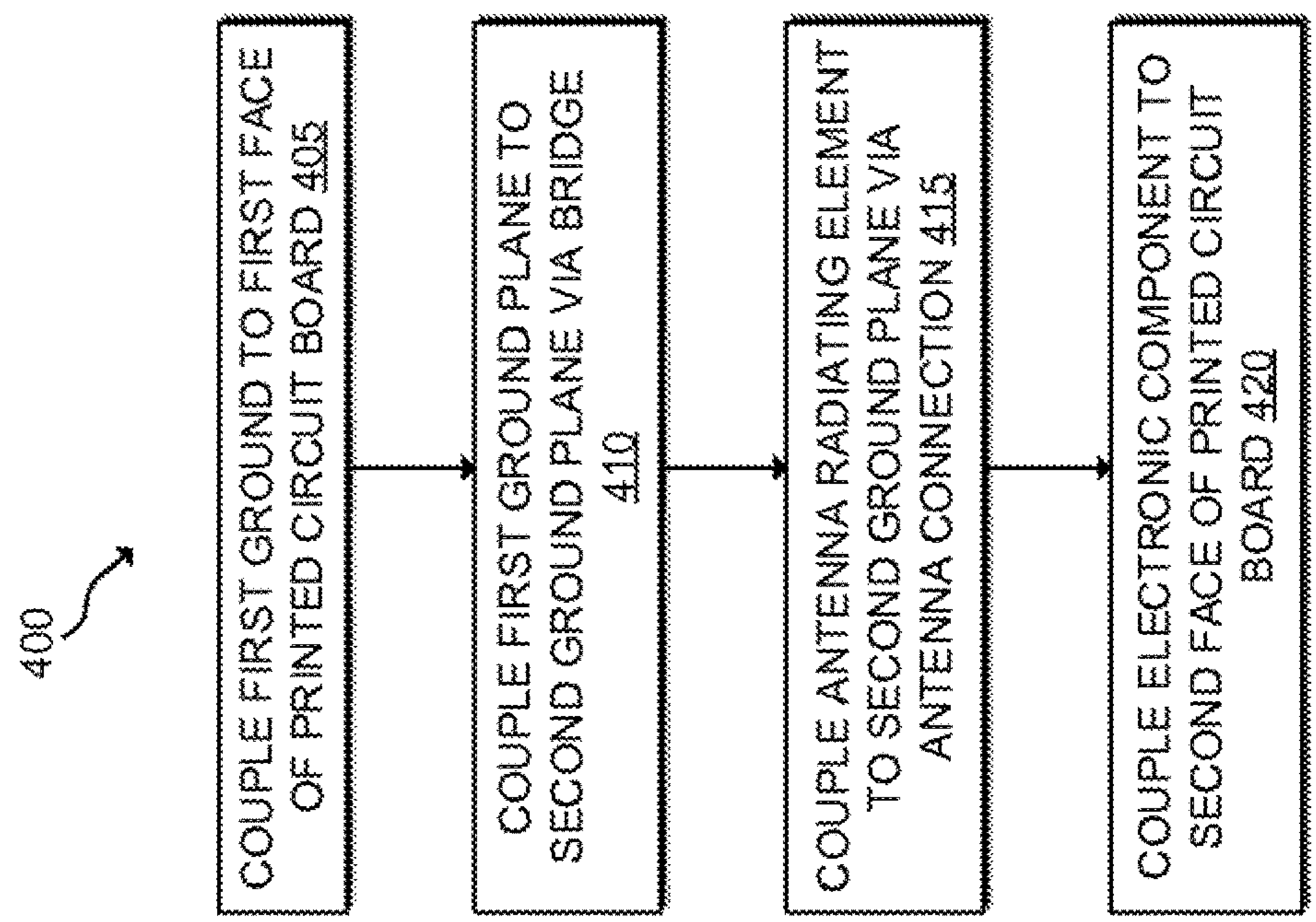

400
COUPLE FIRST GROUND TO FIRST FACE OF PRINTED CIRCUIT BOARD 405
COUPLE FIRST GROUND PLANE TO SECOND GROUND PLANE VIA BRIDGE 410
COUPLE ANTENNA RADIATING ELEMENT TO SECOND GROUND PLANE VIA ANTENNA CONNECTION 415
COUPLE ELECTRONIC COMPONENT TO SECOND FACE OF PRINTED CIRCUIT BOARD 420

FIG. 4A

ANTENNA WITH BRIDGED GROUND PLANES

BACKGROUND

Antennas are electrical devices that convert electrical power into electromagnetic waves and vice versa. In many antenna applications, such as in mobile computing devices, the size of a device may restrict the size of an antenna and its ground plane, which may affect performance of the antenna. For example, the bandwidth and efficiency of an antenna may be affected by the overall size, geometry, and dimensions of the antenna and the ground plane. Furthermore, an antenna's close proximity to other electronic components of a device may cause interfering noise between the antenna and the components.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description references the drawings, wherein:

FIG. **1** is a block diagram of an example antenna system with bridged ground planes;

FIG. **2**A is a block diagram of an example antenna system with bridged ground planes having a bridge passing through a motherboard;

FIG. **2**B is a cross-sectional side view of an example antenna system with bridged ground planes;

FIG. **3** is a block diagram of an example cornputing device having an antenna system with bridged ground planes;

FIG. **4**A is a flowchart of an example method for improving performance of an antenna system; and

FIG. **4**B is a flowchart of an example method for improving performance of an antenna system including filtering noise.

DETAILED DESCRIPTION

Due to the current trend of decreasing sizes for mobile devices such as cellphones, tablet computers, etc., there has been significant interest in developing smaller, space-efficient antenna systems. Challenges arise because antennas need a large enough ground plane to operate at desired frequencies. Furthermore, with decreasing device size, electrical components and wiring inside the device become placed closer together, potentially leading to more unwanted electrical noise.

Examples disclosed herein provide for antenna systems with bridged ground planes. In example implementations, an antenna system includes two ground planes coupled via a conducting bridge. Generally, one ground plane connects to an antenna radiating element that provides the conversion between radio frequencies and electrical signals. A second ground plane may be a larger ground plane connected to a face of a motherboard of the device. By leveraging the bridge scheme, the larger motherboard ground plane may be used in addition to the first antenna ground plane to reflect radio waves. Furthermore, examples disclosed herein may include a filter scheme to filter noise between the antenna radiating element and other components of the antenna system. In this manner, example antenna systems disclosed herein minimize the required space of the antenna system by leveraging the bridge between an antenna ground plane and an adjacent motherboard ground plane.

Referring now to the drawings, FIG. **1** depicts an example antenna system **100** with bridged ground planes. Antenna

system **100** may be an electronic system that converts electrical power into radio waves (i.e., electromagnetic waves) and vice versa for transmitting and receiving data and/or communication. In transmission, antenna system **100** may convert an electric current to electromagnetic waves, which may be transmitted as radio frequencies. In receiving, antenna system **100** may intercept some power of an electromagnetic wave of a certain frequency to produce an electric current.

As depicted in FIG. **1**, antenna system **100** may have a printed circuit board **110**, a first ground plane **120**, a bridge **130**, a second ground plane **140**, an antenna connection **150**, an antenna radiating element **160**, and at least one electronic component **170**. First ground plane **120** may be coupled to a first face **112** of printed circuit board **110**. Bridge **130** may couple first ground plane **120** to second ground plane **140**. Antenna connection **150** may couple antenna radiating element **160** to second ground plane **140**. Electronic component **170** may be coupled to a second face **114** of printed circuit board **110**.

Printed circuit board **110** may be a mechanical support that electrically connects electronic components using conductive pathways between different electronic components and between printed circuit board **110** and electronic components. For example, printed circuit board **110** may be a motherboard or some other type of structure. In some implementations, printed circuit board **110** may have conductive tracks, pads, and other features etched from copper sheets laminated onto a non-conductive substrate. Printed circuit board **110** may be planar in configuration, having a first face **112** and a second face **114**.

First ground plane **120** may be coupled to first face **112** of printed circuit board **110**. First ground plane **120** may be an electrically conductive surface. When coupled to printed circuit board **110**, first ground plane **120** may serve as a return path for current from different components on printed circuit board **110**. In some examples, first ground plane **120** may cover the entire first face **112** of printed circuit board **110**. First ground plane **120** may have an electrically conducting material, such as a layer of copper foil. Generally, first ground plane **120** may have a thin conducting layer.

Bridge **130** may couple first ground plane **120** to second ground plane **140**. In one example, bridge **130** includes a copper foil. In some examples, such as illustrated in FIG. **1**, second ground plane **140** is coupled to first ground plane **120** on first face **112** of printed circuit board **110**. In other words, first ground plane **120** and second ground plane **140** are positioned closer to first face **112** than to second face **114**. Alternatively, in other examples, first ground plane **120** and second ground plane **140** may be coupled on different faces of printed circuit board **110**. For example, second ground plane **140** may be on second face **114** of printed circuit board **110** and coupled to first ground plane **120** by bridge **130** which passes through printed circuit board **110**. These and similar examples are discussed in detail in relation to FIG. **2**A and FIG. **2**B.

Second ground plane **140** may be an antenna ground plane, which may be an electrically conducting surface that reflects radio waves from other elements, such as antenna radiating element **160**. In some examples, second ground plane **140** may be at least a quarter of the wavelength of a radio wave in size in order to function as an antenna ground plane for that radio wave. Second ground plane **140** may be electrically conductive. For example, second ground plane **140** may be a layer of a metal foil, such as copper. Like first ground plane **120**, second ground plane **140** may generally be a thin layer.

When second ground plane **140** and first ground plane **120** are coupled by bridge **130**, first ground plane **120** may be leveraged to boost the performance of second ground plane **140**. In some examples, such as ones described herein, first ground plane **120** may be larger than second ground plane **140** because first ground plane **120** may cover the entire first face **112** of printed circuit board **110**. Accordingly, by leveraging the larger first ground plane **120**, antenna system **100** may be resonant at lower frequencies than would be possible with solely using second ground plane **140**.

Antenna connection **150** may couple antenna radiating element **160** to second ground plane **140**. Antenna connection **150** may include a transmission line, where electric current is fed to and from antenna radiating element **160**. The transmission line may be a number of different kinds of feeds, including an inset feed, a quarter-wavelength transmission line, a probe feed, a coupled/indirect feed, or an aperture feed. In addition, antenna connection **150** may include an electrical shorting pin coupled between first ground plane **140** and antenna radiating element **160**. The shorting pin may operate to decrease the required size for the antenna. In some examples, the shorting pin may be placed at one end of antenna radiating element **160**, and a transmission line may be placed between the shorted end and the opposite end of antenna radiating element **160**. Furthermore, a shorting pin of antenna connection **150** may be a plate in some examples. Adjusting the width of the shorting plate may alter the resonant frequency of antenna radiating element **160**.

Antenna connection **150** may include a number of materials, such as a conducting metal. In some examples, antenna connection **150** may include components made of copper. Lastly, antenna connection **150** may include other components, such as a capacitor coupled between second ground plane **140** and antenna radiating element **160**. For example, the capacitor may operate to balance the capacitance and inductance of the antenna.

Antenna radiating element **160** may be a patch or other shape that radiates and receives radio waves. In some instances, antenna radiating element **160** may be a thin, polygonal-shaped patch. Antenna radiating element **160** may have an electrically conducting material, typically a metal. In many implementations, antenna radiating element **160** may be made of copper. In some examples, a substrate separates antenna radiating element **160** and second ground plane **140**. in other words, second ground plane **140** and antenna radiating element **160** may sit on opposite faces of the substrate. A substrate may have a dielectric material that facilitates fringing electric fields between second ground plane **140** and antenna radiating element **160**. Fringing electric fields may allow the system to operate similarly to a patch antenna or planar inverted-f antenna. A substrate may be any material with a dielectric constant, including mechanical structures or air. For the former examples, a substrate may provide mechanical support to the structure and may be, for example, a circuit board.

At least one electronic component **170** may be coupled to second face **114** of printed circuit board **110**. Electronic component **170** may be any device that may be operable while coupled to printed circuit board **170**. In some instances, electronic component **170** may be an electrical device that may operate on a motherboard. For example, electronic component **170** may be an integrated circuit or integrated circuit package, central processing unit, memory device, resistors, capacitors, and various other components. In some other instances, electronic component **170** may be an optical or other type of device that may operate with a circuit system. It should be noted that electronic component, as used herein, does not include first ground plane **120**, bridge **130**, second ground plane **140**, antenna connection **150**, or antenna radiating element **160**. In some examples, all electronic components **170** that are coupled to printed circuit board **110** are coupled to second face **114** of printed circuit board **110**. In other words, no electronic components are coupled to first face **112** of printed circuit board **110**. For example, first face **112** has first ground plane **120** coupled to it and no electronic components.

FIG. **2**A depicts an example antenna system **200** with bridged ground planes having a bridge **230** passing through a motherboard **210**. Similar to antenna system **100** of FIG. **1**, antenna system **200** may be an electronic system that converts electrical power into radio waves (Le., electromagnetic waves) and vice versa for transmitting and receiving data and/or communication. Antenna system **200** may have a motherboard **210**, a first ground plane **220**, a bridge **230**, a second ground plane **240**, an antenna connection **250**, an antenna radiating element **260**, and at least one electronic component **270**.

Motherboard **210** may be a printed circuit board that supports and electrically connects various devices and components. First ground plane **220** may be coupled to a first face **212** of motherboard **210**, which would be the bottom face of motherboard **210** as depicted in FIG. **2**A. Dotted lines as used in the figures represents an element that is below, under, or otherwise concealed from direct view. Bridge **230** may couple first ground plane **220** to second ground plane **240**. Antenna connection **250** may couple antenna radiating element **260** to second ground plane **240**. Electronic component **270** may be coupled to a second face **214** of motherboard **210**.

In some examples, such as the one depicted in FIG. **2**A, first ground plane **220** and second ground plane **240** may be coupled on different faces of motherboard **210**. For example, second ground plane **240** may be on second face **214** of printed circuit board **210** and coupled to first ground plane **220** by bridge **230** which passes through motherboard **210**. In such examples, second ground plane **240** and electronic component **270** may both be coupled to the same face of motherboard **210**, which is second face **214** in the example depicted. Bridge **230** may have an electrically conducting material, such as a copper foil.

Second ground plane **240** may have a variety of shapes. For example, second ground plane **240** may have a polygonal shape. In some implementations, second ground plane **240** may be a rectangular foil of copper. In examples where second ground plane **240** has a rectangular shape, bridge **230** may couple each edge of second ground plane **240** to first ground plane **220**. Alternatively, antenna system **200** may have multiple bridges **230** that couple each edge of second ground plane **240** to first ground plane **220**. Coupling each edge of second ground plane **240** to first ground plane **220** via bridge **230** may help maintain zero volt differential on the ground planes.

FIG. **2**B is a cross-sectional side view of example antenna system **280** with bridged ground planes. Similar to antenna system **200** of FIG. **2**A, antenna system **280** may include a motherboard **210**, a first ground plane **220**, a bridge **230**, a second ground plane **240**, an antenna connection **250**, an antenna radiating element **260**, and at least one electronic component **270**. Additionally, antenna system **280** may have a moat **285** and at least one filter component **290**. As shown in FIG. **2**B, first ground plane **220** may be on a first face **212** of motherboard **210**, and second ground plane **240** may be on second face **214**. Bridge **230** may pass through motherboard **210** to couple first ground plane **220** and second ground plane **240**.

Moat **285** may separate second ground plane **240** from directly contacting second face **214** of motherboard **210**. Physically separating second ground plane **240** from motherboard **210** may serve to prevent electronic interference between motherboard **210** and the rest of antenna system **280**, including antenna radiating element **260**. The width of moat **285** may vary with each implementation. In some examples, moat **285** may have a width of about one to two millimeters. Moat **285** may be cut from second face **114** to create a gap between the edges of second ground plane **240** and second face **114**. Alternatively, as shown in FIG. 2B, moat **285** may have a physical structure that is placed between second ground plane **240** and second face **114** of motherboard **210**.

Antenna system **280** may include at least one filter component **290**. Filter component **290** may be a device or component that mitigates noise travelling from motherboard **210** to antenna radiating element **260** and from antenna radiating element **260** to motherboard **210**. Noise may be random fluctuations in electrical signals that may interfere with intended operations of electric devices and systems. For example, due to the close proximity of electronic components **270** to the other components of antenna system **280**, unwanted electrical noise may interfere between the operations of electronic component **270** and the other components, such as antenna radiating element **260**.

Filter component **290** may include a number of devices or components that operate to filter a number of types of noise, including, but not limited to, thermal noise, shot noise, flicker noise, and other forms of electrical noise. Non-limiting examples of filter component **290** may include ferrite beads, capacitors, inductors, faraday cages, shielding, wire twists, and notch filters. In some examples, such as the one depicted by FIG. 2B, filter component **290** may be attached or be a portion of bridge **230**. In one example, filter component **290** may be attached to bridge **230** and include at least one of a ferrite bead, an inductor, and a capacitor. In such examples where bridge **230** couples each edge of second ground plane **240** to first ground plane **220**, each edge or side of bridge **230** may include at least one filter component **290**.

Filter component **290** may be designed to filter noise at certain frequencies. For example, antenna system **280** may be designed to send and receive radio waves of certain frequencies. Accordingly, filter component **290** may be designed to boost the performance and reliability of antenna system **280** by filtering noise at desired frequencies. In one example, an antenna system **280** utilized in a mobile phone may have a filter component **290** that targets noise caused by signals in the WWAN/LTE frequencies bands.

FIG. **3** depicts an example computing device **300** having an antenna system **320** with bridged ground planes. Computing device **300** may be, for example, a notebook computer, tablet computer, cellular phone, PDA, communications device such as a radio, wireless server, router, or any other electronic device that may utilize an antenna system. In the example implementation of FIG. **3**, computing device **300** includes a processor **310**.

Processor **310** may be one or more central processing units (CPUs), semiconductor-based microprocessors, and/or other hardware devices suitable for retrieval and execution of computer instructions. In example implementations where computing device may communicate with a mobile network, for example a cellular network or a wireless local area network, antenna system **110** may operate to convert electronic waves of a mobile network into an electrical current, and vice versa, to enable exchanges of data between computing device **300** and a network.

Similar to example antenna system **100** described in detailed in relation to FIG. **1**, antenna system **320** may include a motherboard **325**, first ground plane **330**, second ground plane **335**, bridge **340**, antenna radiating element **345**, antenna connection **350**, and electronic component **355**. First ground plane **330** may be coupled to a first face of motherboard **325**. Bridge **340** may couple first ground plane **330** to second ground plane **335**. Antenna radiating element **345** may be coupled to second ground plane **335** via antenna connection **350**, and electronic component **355** may be coupled to a second face of motherboard **325**. As described above, antenna system **320** may reduce the design dimensions of computing device **300** by leveraging the bridge design between second ground plane **335**, which may operate as an antenna ground, and first ground plane **330**, which may operate as a motherboard ground.

In some examples, second ground plane **335** may be coupled by bridge **340** to the second face of motherboard **325**, opposite first ground plane **330** which is coupled to the first face of motherboard **325**. In such examples, bridge **340** may pass through motherboard **325**. Furthermore, antenna system **320** may, in some examples, include at least one filter component for filtering noise from motherboard **325** to antenna radiating element **345** and vice versa. Further details regarding filter components are discussed in relation to FIG. 2B.

FIG. **4A** is a flowchart of an example method **400** for improving performance of an antenna system, which may include **405** for coupling a first ground plane to a first face of a printed circuit board; **410** for coupling the first ground plane to a second ground plane via a bridge which has at least one filter component; **415** for coupling an antenna radiating element to the second ground plane via an antenna connection; and **420** for coupling at least one electronic component to a second face of the printed circuit board. Although execution of method **400** is herein described in reference to antenna system **100** of FIG. **1**, other suitable parties for implementation of method **400** should be apparent, including, but not limited to, antenna system **200** of FIG. **2**A and antenna system **280** of FIG. **2**B. It should further be understood that method **400** is not limited by the sequence described in relation to the example herein. **405**, **410**, **415**, **420** may be performed in a variety of sequential or concurrent combinations.

Method **400** may start in **405**, where first ground plane **120** is coupled to first face **112** of printed circuit board **110**. First ground plane **120** may be an electrically conductive surface that may serve as a return path for current from different components on printed circuit board **110**. In some examples, first ground plane **120** may cover the entire first face **112** of printed circuit board **110**. First ground plane **120** may have an electrically conducting material, such as a layer of copper foil. First ground plane **120** may have varying thicknesses, but generally, it has a thin conducting layer.

After coupling first ground plane **120**, method **400** may proceed to **410**, where second ground plane **140** is coupled to first ground plane **120** via bridge **130**, The coupling by bridge **130** may form an electrically conducting path between first ground plane **120** and second ground plane **140**. In some examples, bridge **130** may have a thin conducting material, such as copper foil. As described in detail above, second ground plane **140** may be coupled to first ground plane **120** on first face **112** of printed circuit board

110. Alternatively, in other examples, first ground plane **120** and second ground plane **140** may be coupled on different faces of printed circuit board **110** with bridge **230** passing through printed circuit board **110**.

Second ground plane **140** may be antenna ground plane, which may be an electrically conducting surface that reflects radio waves from other elements, such as antenna radiating element **160**. In some examples, second ground plane **140** may be at least a quarter of the wavelength of a radio wave in size in order to function as an antenna ground plane for that radio wave. Second ground plane **140** may have an electrically conducting material, such as a layer of copper foil. When second ground plane **140** and first ground plane **120** are coupled by bridge **130**, first ground plane **120** may be leveraged to boost the performance of second ground plane **140**. In some examples, such as ones described herein, first ground plane **120** may be larger than second ground plane **140** because first ground plane **120** may cover the entire first face **112** of printed circuit board **110**. Accordingly, by leveraging the larger first ground plane **120**, antenna system **100** may be resonant at lower frequencies than would be possible with solely using second ground plane **140**.

After coupling the ground planes via bridge **130**, method **400** may proceed to **415**, where antenna radiating element **160** is coupled to second ground plane **140** via antenna connection **150**. As described in detail above, antenna connection **150** may include a transmission line, where electric current is fed to and from antenna radiating element **160**, and an electrical shorting pin or plate which may operate to decrease the required size for the antenna.

Antenna radiating element **160** may be a patch or other shape that radiates and receives radio waves. Antenna radiating element **160** may have an electrically conducting material, such as copper. In some examples, a substrate separates antenna radiating element **160** and second ground plane **140**. In other words, second ground plane **140** and antenna radiating element **160** may sit on opposite faces of the substrate. A substrate may have a dielectric material that facilitates fringing electric fields between second ground plane **140** and antenna radiating element **160**. Fringing electric fields may allow the system to operate similarly to a patch antenna or planar inverted-f antenna. A substrate may be any material with a dielectric constant, including mechanical structures or air. For the former examples, a substrate may provide mechanical support to the structure and may be, for example, a circuit board.

After coupling antenna radiating element **160** to second ground plane **140**, method **400** may proceed to **420**, where electronic component **170** is coupled to second face **114** of printed circuit board **110**. Electronic component **170** may be a variety of electrical devices that may operate while coupled to printed circuit board **170**. For example, electronic component **170** may be a central processing unit, memory devices, and various other components. It should be noted that electronic component, as used herein, does not include first ground plane **120**, bridge **130**, second ground plane **140**, antenna connection **150**, or antenna radiating element **160**. In some examples, all electronic components **170** that are coupled to printed circuit board **110** are coupled to second face **114** of printed circuit board **110**. in other words, no electronic components are coupled to first face **112** of printed circuit board **110**.

FIG. **4**B is a flowchart of an example method **450** for improving performance of an antenna including filtering noise. Method **450** may include method **400** and block **455** for filtering noise from the motherboard (or other circuit board) to the antenna radiating element and from the antenna radiating element to the motherboard. Although execution of method **450** is herein described in reference to antenna system **280** of FIG. **2**B, other suitable parties for implementation of method **450** should be apparent, including, but not limited to, antenna system **100** of FIG. **1** and antenna system **200** of FIG. **2**A. It should further be understood that **405**, **410**, **415**, and **420** are not limited by the sequence described in relation to the example herein. **405**, **410**, **415**, **420** may be performed in a variety of sequential or concurrent combinations.

455 includes filtering noise from motherboard **210** to antenna radiating element **260** and from antenna radiating element **260** to motherboard **210**. During operations of antenna system **280**, noise may be caused by random fluctuations in electrical signals traveling through the system that may interfere with intended operations of antenna system **280**. Antenna system **280** may include at least one filter component **290** that filters unwanted noise. Filter component **290** may include a number of devices or components that filter thermal noise, shot noise, flicker noise, or other forms of electrical noise. Non-limiting examples of filter component **290** may include ferrite beads, capacitors, inductors, faraday cages, shielding, wire twists, and notch filters.

Filter component **290** may be designed to filter noise at certain frequencies. For example, antenna system **280** may be designed to send and receive radio waves of certain frequencies. Accordingly, filter component **290** may be designed to boost the performance and reliability of antenna system **280** by filtering noise at desired frequencies. In one example, an antenna system **280** utilized in a mobile phone may have a filter component **290** that targets noise caused by signals in the WWAN/LTE frequencies bands.

The foregoing describes a number of examples for antenna systems with bridged ground planes. It should be understood that the antenna systems described herein may include additional components and that some of the components described herein may be removed and/or modified without departing from the scope of the antenna system. It should also be understood that the components depicted in the figures are not drawn to scale and thus, the components may have different relative sizes with respect to each other than as shown in the figures.

What is claimed is:

1. An antenna system in a mobile computing device, comprising: a printed circuit board comprising a motherboard of the mobile computing device; a first ground plane for the motherboard that is coupled to a first face of the printed circuit board; a bridge coupling the first ground plane to a second ground plane; and an antenna radiating element coupled to the second ground plane via an antenna connection; further comprising an additional component coupled between the second ground plane and the antenna radiating element, the additional component comprising a capacitor to balance capacitance and inductance of the antenna system.

2. The antenna system of claim **1**, wherein all electronic components that are coupled to the printed circuit board are coupled to a second face of the printed circuit board.

3. The antenna system of claim **1**, wherein the second ground plane is coupled to the first ground plane via the bridge on the first face of the printed circuit board, both the first and second ground planes being on a same side of the printed circuit board.

4. The antenna system of claim **1**, wherein the second ground plane is coupled to the second face of the printed circuit board and wherein the bridge is electrically conducting to electrically connect the first and second ground planes and passes through the printed circuit board.

5. The antenna system of claim **1**, further comprising a moat separating the second ground plane from the second face of the printed circuit board.

6. The antenna system of claim **3**, wherein the first ground plane and the second ground plane are positioned closer to the first face than to the second face of the printed circuit board.

7. The antenna system of claim **1**, wherein the second ground plane comprises a rectangular shape.

8. The antenna system of claim **7**, wherein the bridge couples each edge of the second ground plane to the first ground plane.

9. The antenna system of claim **1**, wherein the antenna system comprises a filter component for filtering noise from the printed circuit board to the antenna radiating element and from the antenna radiating element to the printed circuit board.

10. The antenna system of claim **9**, wherein the filter component comprises one of a ferrite bead, a capacitor, and an inductor.

11. A device with an antenna system comprising:

a circuit board comprising a motherboard of a mobile computing device;

a first ground plane of the motherboard that is coupled to a first face of the motherboard;

an electrically conducting bridge electrically coupling the first ground plane to a second ground plane on a second, opposite face of the circuit board and wherein the bridge passes through the motherboard; and

an antenna radiating element coupled to the second ground plane via an antenna connection;

wherein the antenna system comprises a filter component for filtering noise, the filter component being embedded inside the circuit board.

12. The device of claim **11**, wherein the first ground plan is a return path for current from components of the motherboard.

13. A method, comprising:

coupling a first ground plane to a first face of a printed circuit board;

coupling the first ground plane to a second ground plane via a bridge, wherein the bridge comprises a filter component;

coupling an antenna radiating element to the second ground plane via an antenna connection;

coupling an electronic component to the printed circuit board; and

filtering noise from the printed circuit board to the antenna radiating element and from the antenna radiating element to the printed circuit board with a filter that is embedded interior to material of the circuit board.

14. The method of claim **13**, further comprising using the first ground plane as a return path for current from components on the printed circuit board.

15. The device of claim **11**, wherein the first ground plane is a return path for current from a component coupled to the circuit board.

16. The device of claim **11**, further comprising:

a shorting pin at one end of the antenna radiating element; and

a transmission line between a shorted end and an opposite end of the antenna radiating element.

17. The method of claim **13**, wherein the circuit board is a motherboard.

18. The device of claim **11**, further comprising a moat formed on a surface of the circuit board and disposed between the second ground plane and the circuit board.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 10,340,591 B2
APPLICATION NO. : 15/304931
DATED : July 2, 2019
INVENTOR(S) : Chang-Cheng Hsieh et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

In Column 10, Line 1, Claim 12, delete “plan” and insert -- plane --, therefor.

Signed and Sealed this
Nineteenth Day of November, 2019

Andrei Iancu
Director of the United States Patent and Trademark Office